ISASC

ERNATIONAL SOCIETY OF ANTIQUE SCALE COLLECTOR

NEWSLETTER 5 MAY, 1977

Hello folks! Here is the newsletter you may have been awaiting anxiously. We - Gwen and Alex - do apologise for running late but we have not only hit a desperately busy time at both our Colleges, but have also had to cope with the sudden failure and replacement of our domestic boiler. Also, for Gwen, the climax, the Ranger Guide Diamond Jubilee activities, and for Alex special events in the Sailing Club calender took place.

By the way, please adjust our designation to read "Gwen and Alex Kenton" since Gwen started collecting scales - with a "C" spring balance and now we both "do it", and also struggle to find house room for related old books.

So to scales, weights etc. Ours feature as part of a wider collection of measuring devices of all kinds: when we "run out" of scales and weights we might tell you about some of the other fascinating items, including some delightful microscopes. First, two bits of museum information:

1. If you are in the South of England, do not miss the Westgate Museum, Winchester, which exhibits standard weights held by the City of Winchester since they were issued - "the finest civic collection of old weights and measures in the country, and the set of weights of the reign of Edward III is unique". As it is a small museum, the curator was most helpful to us with regard to photography, but our transparencies are not readily reproducible here.

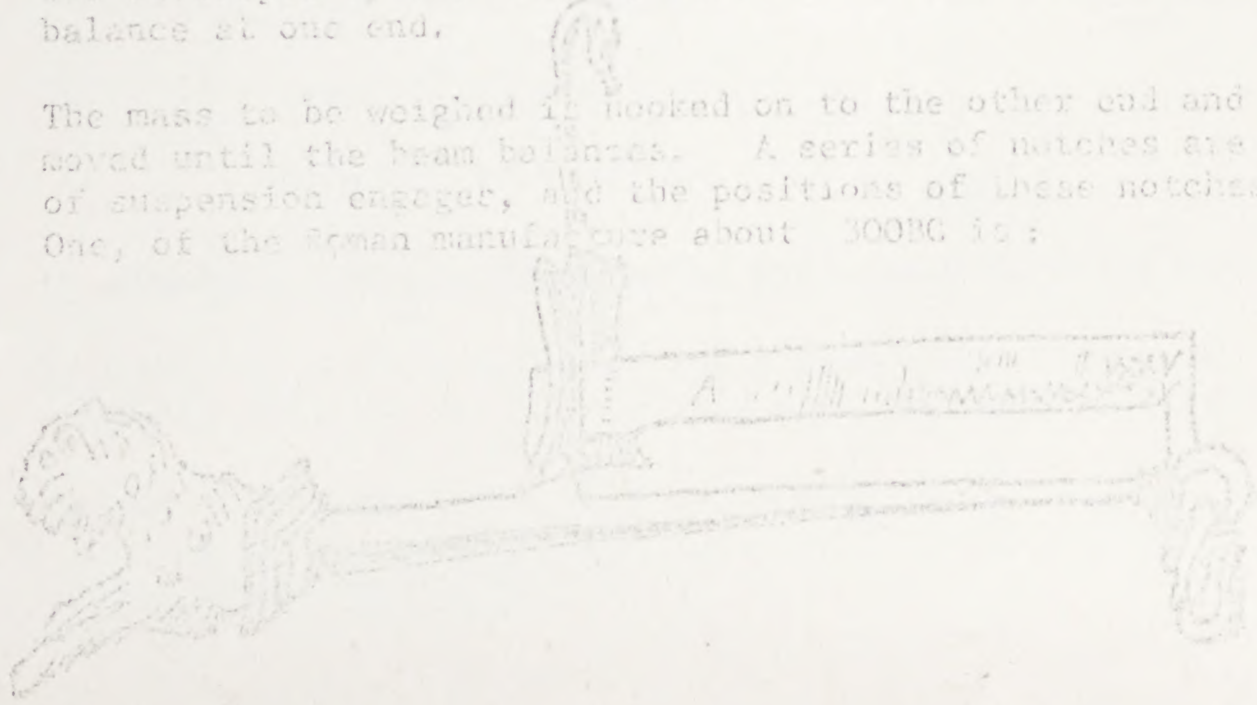
2. The Science Museum, London, SW7 2DD, has an excellent service of photographs prepared to order. Write to "The Director and Secretary" for price lists and enquiries concerning any proposed reproductions. Consult the catalogues in the information office when you visit the museum, and order by the negative numbers: you have plenty to choose from.

Second: our contribution to the ISASC "information bureau" follows - the development of the Steelyard.

## BISMAR

Up to about 400BC, only equal arm balances had been used and these obviously needed sets of weights. About this time a weighing beam, called the BISMAR, was developed by the Romans, based on unequal arms with a single fixed counterbalance at one end.

The mass to be weighed is hooked on to the other end and the point of suspension moved until the beam balances. A series of notches are cut in which the point of suspension engages, and the positions of these notches form the calibration. One, of the Roman manufacture about 300BC is :



The main disadvantage of the Bismar is its great inaccuracy. As will be shown later, the graduations are not at equal distances apart for equal increases of mass, but get closer and closer together, they become very crowded at the high weight end as the suspension gets closer to the mass being weighed. The beam is thus unstable since a very small movement of the fulcrum upsets the balance.

The Bismar is mentioned by Aristotle (384-322 BC) in his "Mechanica", and, in spite of its inaccuracies, spread widely. Its use continued, in an improved form, in Russia, Finland and Scandinavia as late as 1939. The modern versions were made of steel or brass with machine engraved divisions and hard steel knife edges on the fulcrum, but were still inaccurate at the higher end due to the basic faulty design.

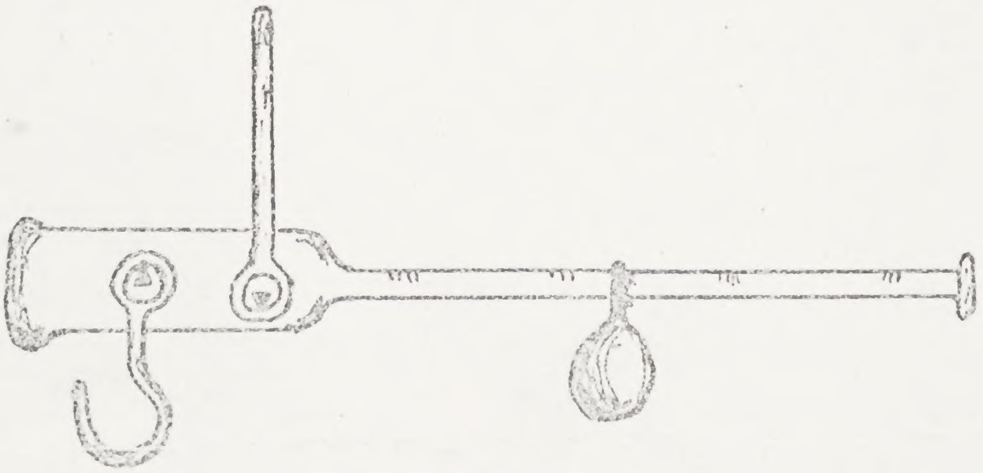
The Bismar arrived in England about 400 AD, but, due to a recognition of its inherant inaccuracy and potential of abuse, was outlawed in 1352 AD by Edward III after 50 years of pressure by the Merchant Guilds of London. Its use did not cease until the Archbishop of Canturbury in 1428 AD threatened excommunication to all who still used it.

ROMAN STEELYARD

This is the name given to the standard steelyard which was invented about 100 BC. Its basic principle is a fixed fulcrum and moving counterbalance weight sliding on the beam on the opposite side to the load. It will be shown that the distance between graduations remains equal for equal differences in load

The earliest description, about 20 BC, is by the Roman author Vitruvius in his "Of the Principles of Mechanics". The description is of a steelyard with two separate fulcrums and two scales so that by turning the beam over the range could be increased.

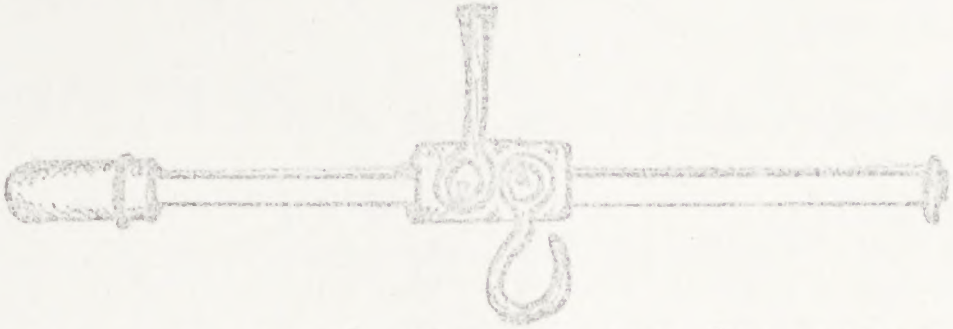
This eliminated the faults of the Bismar, and was good enough for normal commercial use, though obviously not as accurate or sensitive as a good equal arm balance. The only real improvements made were to the methods of suspension.



Weighbridges and platform scales are often based on this principle.

## SLIDING BEAM STEELYARD

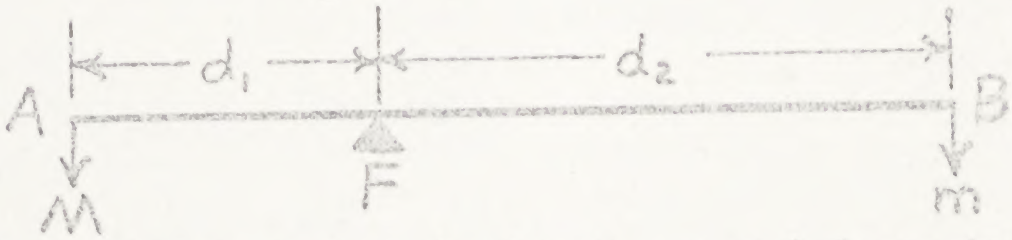
A third version of the steelyard is one in which the entire beam slides through a housing supported by the fulcrum and supporting the load. The beam assists the action of the counterpoise. The load of course, remains at a fixed distance from the fulcrum.



Now, a little mathematics! Skip the next few paragraphs if you wish.

How do they work?

All beam balances are based on the mathematical principle of moments. If AB is a beam (of negligible mass) supported at F by a fulcrum such that AF = $d_1$, FB = $d_2$ and masses M,m are suspended at A and B respectively then, when the masses balance, $Md_1 = md_2$.

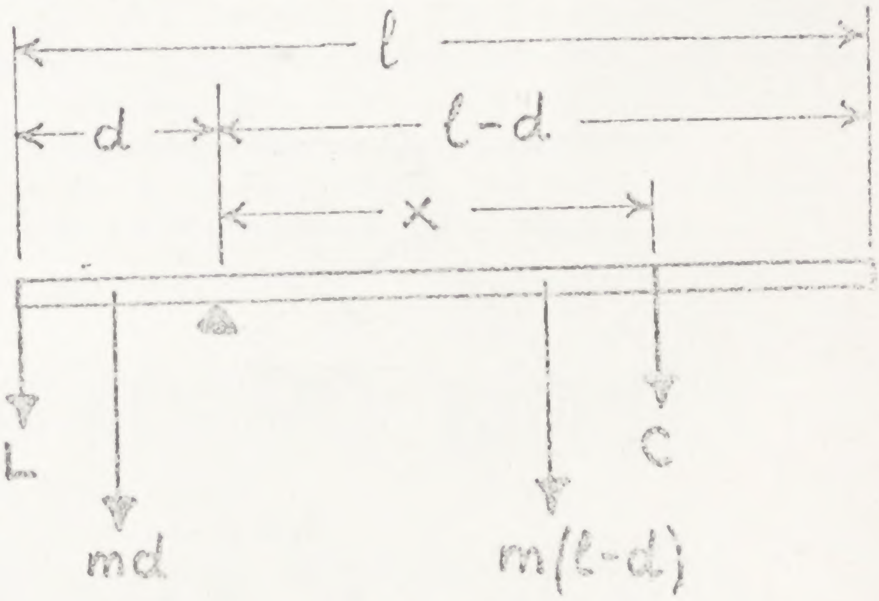


In the equal arm balance, $d_1 = d_2$ thus M = m at balance involving a direct comparison of masses with the geometry playing no part except in sensitivity.

For the unequal arm balance, $m = Md_1/d_2$ so that the division of the beam has an effect on the measurement of the load. This formula is based on the beam having negligible weight itself compared with the masses. In a real steelyard this is not so, and the mass of the parts of the beam on either side of the fulcrum must be considered.

In all that follows, for simplicity the beams will be considered as having uniform cross section. When numbers are put into the formulae the beam length ($\ell$) will be taken as 20 inches with a mass (m) of 1/10 lb per inch. The counterpoise weight (C) will be 4 lb. Where applicable, the distance (d) between load (L) and fulcrum will be 1 inch. These are roughly the dimensions of a steelyard in our collection.

Roman Steelyard



Taking moments about the fulcrum:

$$Ld + md\left(\frac{d}{2}\right) = Cx + M(\ell - d)\left(\frac{\ell - d}{2}\right)$$

$$Ld = Cx + \frac{m}{2}(\ell - d)^2 - \frac{md^2}{2}$$

$$= Cx + \frac{m}{2}(\ell - 2d)\ell$$

$$\therefore L = \frac{C}{d}x + \frac{m\ell(\ell - 2d)}{2d}$$

Since C, d, m, $\ell$ are constant for a particular steelyard, the load is measured directly by the distance x of the counterpoise from the fulcrum.

In our steelyard, $C = 4$, $\ell = 20$, $m = \frac{1}{10}$, $d = 1$

$$\therefore L = \frac{4}{1}x + \frac{1 \times 20\ (20 - 2)}{10 \times 2 \times 1}$$

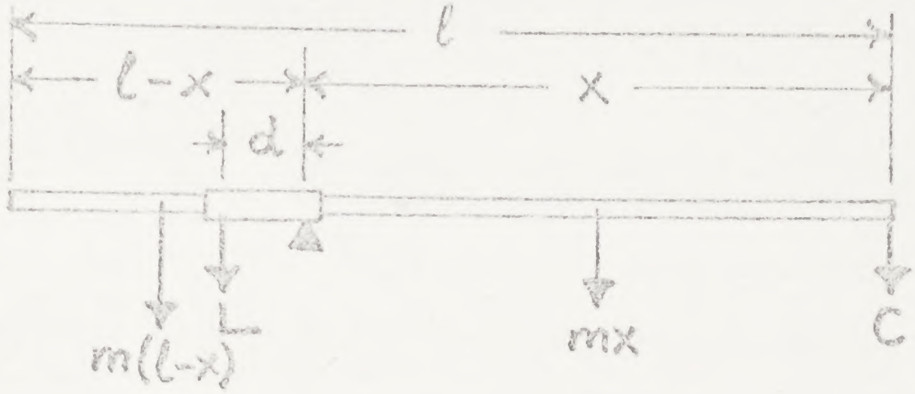
∴ $L = 4x + 18.$

Calibration:

| | | | | | | |
|---|---|---|---|---|---|---|
| x(in) | 0 | 1 | 2 | 3 ........ | 18 | 19 |
| L(ℓb) | 18 | 22 | 26 | 30 ........ | 90 | 94 |

The minimum load that can be weighed is 18 lb and the maximum 94 lb with each ¼ inch representing an increase of 1 lb.

Sliding Beam Steelyard.



Moments: $Ld + m(\ell - x)(\frac{\ell - x}{2}) = Cx + mx(\frac{x}{2})$

$$Ld = Cx + \frac{mx^2}{2} - \frac{m}{2}(\ell - x)^2$$
$$= Cx + \frac{m}{2}(2x - \ell)\ell$$
$$= Cx + m\ell x - \frac{m\ell^2}{2}$$
$$= (C + m\ell)x - \frac{m\ell^2}{2}$$

$$\therefore L = \frac{(C + m\ell)}{d}x - \frac{m\ell^2}{2d}$$

Again, x gives a direct measure of L .

In our steelyard $L = \left(\frac{4 + \frac{1}{10} \times 20}{1}\right) x - \frac{1 \times 20 \times 20}{10 \times 2 \times 1}$

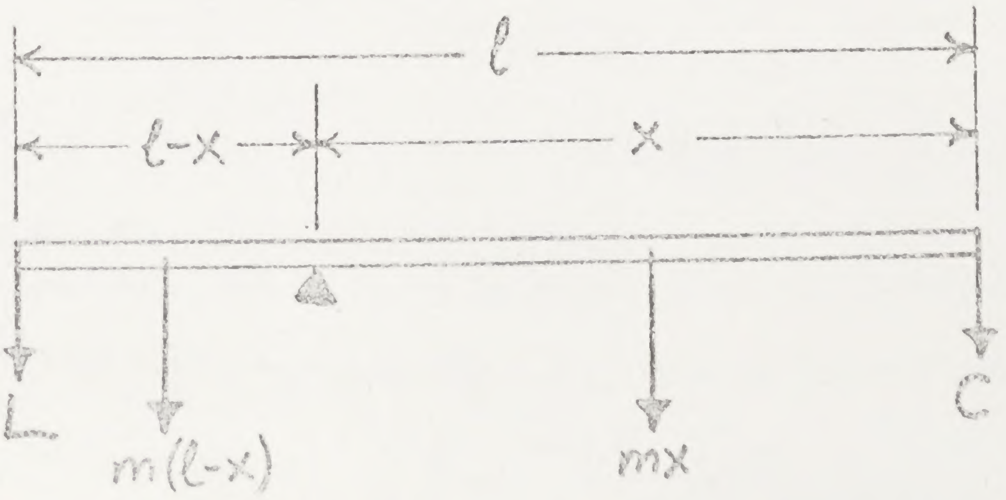
∴ $L = 6x - 20.$

Calibration (L cannot be negative)

| | | | | | | |
|---|---|---|---|---|---|---|
| x (in) | 3⅓ | 4 | 5 | 6 ......... | 18 | 19 |
| L( b) | 0 | 4 | 10 | 16 ......... | 88 | 94 |

The load can vary from zero to a maximum of 94 lbs, with a 1 lb increase represented by a distance of 1/6 inch.

Bismar



Moments: $L(\ell - x) + m(\ell - x)\left(\frac{\ell - x}{2}\right) = Cx + mx\left(\frac{x}{2}\right)$

$$
\begin{aligned}
L(\ell - x) &= Cx + \frac{mx^2}{2} - \frac{m(\ell - x)^2}{2} \\
&= Cx + \frac{m}{2}(2x - \ell)\ell \\
&= Cx + m\ell x - \frac{m\ell^2}{2} \\
&= (C + m\ell)x - \frac{m\ell^2}{2}
\end{aligned}
$$

$$\therefore \quad L = \frac{(C + m\ell)x}{\ell - x} - \frac{m\ell^2}{2(\ell - x)}$$

Thus the load is not directly proportional to the distance x.

In our steelyard $L = \frac{(4 + 1/10 \times 20)x}{20 - x} - \frac{1 \times 20 \times 20}{10 \times 2\ (20 - x)}$

$$= \frac{6x}{20 - x} - \frac{20}{20 - x}$$

$$\therefore \; L = \frac{6x - 20}{20 - x}$$

Calibration:

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| x(in) | 3.33 | 5.71 | 7.5 | 8.89 | 10 | ... | 18 | ... | 18.9796 | 18.9899 | 19 |
| L($\ell$b) | 0 | 1 | 2 | 3 | 4 | .... | 44 | ... | 92 | 93 | 94 |

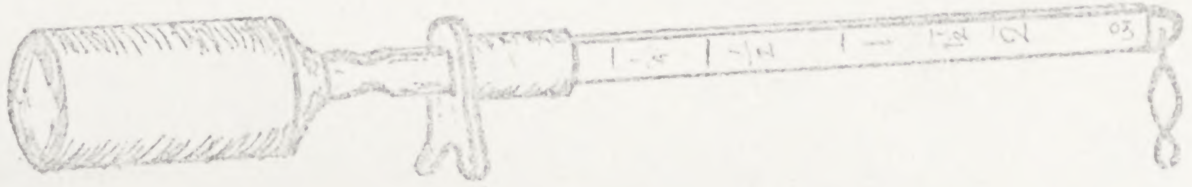
The load increasing from 0 to 1 lb requires a fulcrum shift of about 2.38 inches, while from 93 to 94 lb the shift is only about 1/100 inch, hardly a feasible calibration. The range from 0 to 44 lb is spread over 18 inches while 44 to 94 lb only over 1 inch! This really brings home the design fault in the bismar.

(For the mathematical purist - I have deliberately left a "g" out of each term in the moment equations: it cancels throughout anyway!)

In our collection we have a number of standard steelyards with beam lengths varying from 41 inches down to a tiny one of 4 inches. The large ones were probably ex butchers or farmers, used for weighing carcases or sacks of grain. The very small one is a coin balance. Another has a 9½ inch hickory beam with a very sharp pointed load hook and was used for weighing sacks of wool (to about 8 lb on one scale and 35 lb on the other). We also have the rather nice ivory beam type used in China for weighing opium or silver. These have three points of suspension, three scales and come in nice wooden cases shaped like a violin.

We have one of the sliding beam type, an old Greek market steelyard with a brass pan hanging by three chains for the load, and have never seen a similar one. Does anyone have any of this type?

The only Bismar type is a small coin balance made by Edward Greaves and calibrated ¼ to 4 Tolah Indian on one side and ¼ to 2 oz Brindisi on the other. The movable fulcrum can be rotated round the beam. The load end has a spring clip to hold the coin being weighed, and overall length is 4½ inches.



One "steelyard" in constant use is an old personal weighing machine, the type with a platform on which we stand, a tall pillar protecting the linkage and a beam with sliding counterpoise to 7 lb x 1 oz with extra weights to add to the end of the beam. It weighs up to 20 stones, is accurate to the ounce, and much better than the modern dial type which depend on how one stands as to the weight they indicate. Our one allows no illusions - it tells the hard truth.

Best wishes to all, Gwen & Alec Renton

From our 'Book Collection' -
"Frontispiece" to Medicina Statica:
BEING THE
APHORISMS of SANCTORIUS,
By JOHN QUINCY, M.D.
LONDON:
MDCCXX.